PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES

Volume 7 MAY 15, 1921 Number 5

THE DIFFUSION OF AIR THROUGH WATER IN THE LAPSE OF YEARS[1]

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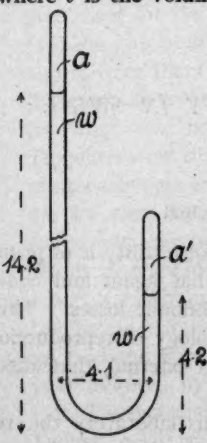
Communicated January 10, 1921

In 1912 I put up a U-tube of the form annexed, containing a charge of water, ww', below the air chambers, aa', both at nearly atmospheric pressure. The tubes were sealed by fusion cautiously, to avoid the presence of flame faces in aa'. They were then put away in a dark vault of nearly constant temperature, for short time ranges, to be examined from time to time as to the displacement of the thread of water within: for it will be seen that the meniscus under a' is at a pressure excess of $h\rho g$ as compared with the meniscus under a. If L is the total length of the thread of liquid in the tube, we may define the coefficient (κ) of diffusion (by volume) by the equation

$$v = \kappa a t (h\rho g)/L$$

where v is the volume diffusing at nearly constant mean pressure in the time t through an area a, the density of liquid being $\rho = 1$. Hence,



$$\kappa = \frac{v}{at}\frac{L}{h\rho g} = \frac{1}{2}\frac{dh}{dt}\frac{L}{h\rho g},$$

where dh/dt is the loss of head per second. The factor ½ appears since the volume lost at a' appears at a, and their sum is equivalent to the loss of head. The amount of diffusion is so small that corrections may be disregarded.

The observations made before the spring of 1914 were not satisfactory because of deficiencies of method. They were, therefore, discarded. Measurement was thereafter made with the cath-

etometer. The following table gives the essential data for the interval of 6 years, 9 months and 6 days with the increment from leap years:

NO.	L cm.	DIAM. INSIDE cm.	AREA cm^2.	DATE	INTERVAL $t \times 10^8$ SEC.	h cm.	$10^8 \frac{dh}{dt}$	$10^{12} \kappa$
I	20.0	0.55	0.24	1914- 3-20 1920-12-26	2.14	10.12 9.89	1.07	1.10
II	15.7	0.82	0.53	1914- 3-20 1920-12-26	2.14	7.59 7.22	1.73	1.87

The two values of κ found are of the same order, but the one for tube II is definitely larger than the one for tube I. This may be due to infinitesimal difference in the separated gases (a,a') of the tubes. But since the tube II has a shorter (L) and wider column, and a meniscus nearer the bend, it is more probable that thermal correction is the cause of the difference; for the inside sectional area of II is about 2.2 times larger than that of I. The data obtained for κ with a cylindrical cartesian diver (Carnegie Publications, No. 186, Washington, 1913, p. 21) about 3 cm. in diameter of 7.05 cm^2. in area, are enormously larger than the above, reading $\alpha = 90 \times 10^{-12}$. The result is in keeping with the enormously larger area and consequent effectiveness of the solution-temperature mechanism which I have described in the preceding paper.[2] Whether in case of tube I, a condition of true diffusion has been reached will have to be ascertained in the lapse of further years. Meanwhile the question whether a long slender cartesian diver may not obviate the discrepancies hitherto encountered is worth consideration.

[1] Advance note from a Report to the Carnegie Institution, Washington, D. C.

[2] These PROCEEDINGS, **6**, 1920 (495–8).

THE INFLUENCE OF AGE ON FERTILITY IN SWINE [1]

BY TAGE ELLINGER

COPENHAGEN, DENMARK

Communicated by R. Pearl, March 10, 1921

In the breeding of domestic animals the problem of fertility is of prime importance. The neglect of this essential factor has again and again caused breeders disappointments and often heavy economic losses. Thus it is desirable to study this chapter of the physiology of reproduction thoroughly and to examine the factors, internal and external, that affect the ability to produce offspring.

During an investigation on these subjects, in this laboratory the results of which are soon to be published, the writer has been confronted

with the question of the influence of age of the sow on the size of her litters. Although a number of records on this and similar subjects have been published from time to time, the writer is of the opinion that the special qualities of his material, and the mathematical treatment of it that it is possible to employ, justify this further publication.

In going over the literature on the influence of age on fertility in mammals, a number of records bearing on the question can be collected. Sarah V. Jones and James E. Rouse[10] have in a recent paper give an extensive summary of the literature, to which paper I only need to refer for further information.

The records published are of two different kinds. First: results of experiments chiefly with rats (King[11]), rabbits (Hammond[8]), and guinea-pigs (Minot[14]). The experiments on swine by Mumford[15] (1917) are of further interest in this connection.

The second group consists of statistical investigations generally using as material the numerous records given in the herd books of the different breeds of domestic animals.

Carlyle and Mc Connell,[6] Pearl,[16] Bell,[3,4] Humphrey and Kleinheinz,[9] Jones and Rouse[10] give records showing that the percentage of multiple births in sheep increases with age up to five years and then again declines. Pearl[16] and Jones and Rouse[10] give similar data for cattle showing a steady increase in the percentage of twin births with age.

Swine have often been subject to investigations of this kind. One of two sources of error have always been present in these. 1. The number of individuals involved have been so limited as to make dependable results unobtainable, or 2. The method of computing has been so rough as to give room for the effect of selection. The usual way of approaching the problem has been to take from herd book records of all available litters and to refer them to the age of their mothers at their birth. In this way it is possible to get a great number of litters from young sows but rather few from older ones as the less desirable animals are disposed of early. The older sows represent only a selected group of the best of those recorded at an early age, and the average size of litters at different ages of the sows are for that reason not directly comparable. Owing to these difficulties the results are very contradictory and uncertain. Rommel[13] found a steady increase in size of litter from one to five years. Frölich and Georgs[7] report a maximum in the second litter and then a decrease in size of the the litters. Machens[12] claims a maximum at the fourth litter. Carmichael and Rice[5] give a table showing an increase in fertility to the third year followed by a decrease.

2. The material used in this investigation consists of 134 sows of native Danish breed[2] which *all* have records from all of their first ten litters. The

records are taken from the Danish herd book Vols. V and VII. All these sows have been kept in state-supervised *breeding centres* under uniform conditions and care. They have all farrowed the first time at about one year of age and from then on been bred regularly producing ca. $2^1/_4$ litter per year, practically without regard to season. The successive litters will for that reason be highly correlated with age, but it seems most convenient to use the litter-number as unit. The average of all litters, being 11.5 pigs, is far above the average shown by swine of the American type, and although these 134 sows undoubtedly are selected group, the great fertility is one of the outstanding and valuable qualities of the breed.

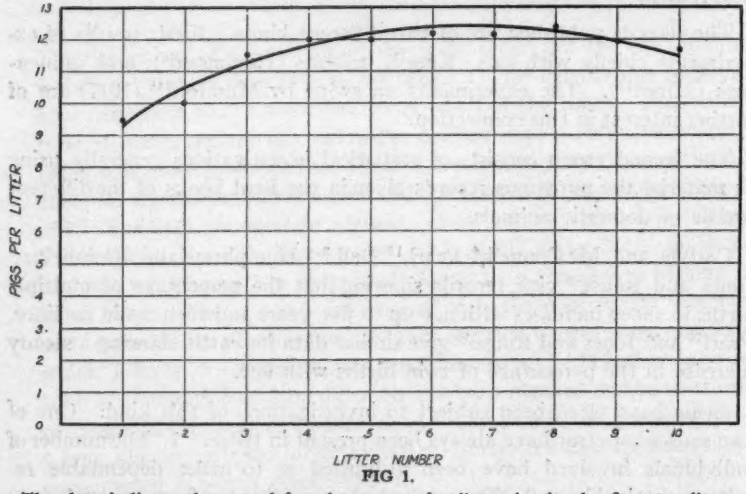


FIG 1.

The dots indicate the actual found averages for litter-size in the first ten litters. The curve is fitted to these valves.

In the second column of table 1 the average sizes of the successive ten litters are given.

TABLE I

LITTER NO.	AVERAGE SIZE OF LITTER	THEORETICAL SIZE OF LITTER
1	9.45	9.25
2	10.01	10.42
3	11.50	11.24
4	12.01	11.81
5	11.99	12.19
6	12.16	12.38
7	12.13	12.39
8	12.34	12.24
9	11.90	11.92
10	11.66	11.43
Average	11.52	11.53

Plotting the series of average values over a base indicating the successive generations (fig. 1) we see that they show an increase in fertility

with age to a certain point followed by a decline. An empirical curve following these plotted points shows a type familiar to us from other biological problems. It is in fact a logarithmic curve. Pearl[17] has shown that the changes in milk flow with age in dairy cattle follow such a logarithmic curve and he has determined its equation.

The writer has now proceeded to form the equation relating fertility to to age in the material at hand, and has in the calculations used the method of moments (Miner[13]).

The general form of the equation is

$$y = a + bx + cx^2 + d\log x$$

where y denotes the size of litter and x the ordinal litter number.

In this special case the equation has been calculated to be the following

$$y = 8.414 + 0.915x - 0.078x^2 + 1.627\log x.$$

By solving the equation for the values of x ranging from 1 to 10 the theoretical average size of the successive litters has been determined. These values are given in the third column of table 1 and they are used in plotting the curve in figure 1. This curve shows a satisfactory agreement with the empirical figures plotted out.

By putting $dy/dx = 0$ and solving for x the litter of maximum size is found to be 6.56th in order.

Summary.—1. Records from 134 sows of native Danish breed all having ten litters to their credit show an increase in fertility up to the 6.56 point in litter order followed by a decrease.

2. The curve relating fertility to age is logarithmic, its equation is calculated, and the curve fitted.

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 35.

[2]The native Danish breed is a white, fertile and hardy hog of bacon type, producing sometimes crossed with Yorkshire boars—the great proportion of the choice bacon exported from Denmark to England.

[3]Bell, A. G. 1904. The multi-nippled sheep of Beinn Bhreagh. *Science, N. S.*, **19**.

[4]Bell, A. G. 1912. Sheep breeding experiments on Beinn Bhreagh. *Ibid.*, **34**.

[5]Carmichael, W. J. and John B. Rice. 1920. Variation in farrow: With special reference to birth weight of pigs. *Univ. Illinois, Agric. Exp. Sta., Bull.* **226**.

[6]Carlyle, W. L. and T. F. Mc Connell. 1902. Some observations on sheep breeding from the Experiment Stations flock records. *Univ. Wisconsin, Agric. Exp. Sta., Bull.* **95**.

[7]Frölich und Georgs. 1911. Fruchtbarkeit und Geschlechtverhältnis beim weissen Edelschwein. *Jahrbuch für wissenschaftliche und praktische Tierzucht*, **6**.

[8]Hammond, John. 1914. On some factors controlling fertility in domestic animals. *J. Agric. Sci.*, **6**.

[9]Humphrey, G. C. and F. Kleinheinz. 1907. Observations on sheep breeding from records of the university flock. 24th *Ann. Rep. Wisconsin Agric. Exp. Sta.*

[10]Jones, S. N. H. and J. E. Rouse. 1920. The relation of dam to observed fecundity in domestic animals. I. Multiple birth in cattle and sheep. *J. Dairy Sci.*, **3**.

[11]King, H. D. 1916. The relation of age to fertility in rat. *Anat. Rec.*, **11**.

[12]Machens, A. 1915. Fruchtbarkeit und Geschlechtsverhältnisse beim veredelten Landschwein. *Berliner Tierärtzliche Wochenschrift*, **31**.

[13]Miner, J. R. 1915. Fitting logarithmic curves by the method of moments. *J. Agric. Res.*, **3**.

[14]Minot, C. S. 1891. Senescence and rejuvenescence. First paper: On the weight of guinea pigs. *J. Physiol.*, **12**.

[15]Mumford, F. B. 1917. *The Breeding of Animals.*

[16]Pearl, R. 1913. Note regarding the relation of age to fecundity. *Science, N. S.*, **37**.

[17]Pearl, R. 1914. On the law relating milk flow to age in dairy cattle. *Proc. Soc. Exp. Biol. Med.*, **12**.

[18]Rommel, G. M. 1907. Inheritance of litter size in Poland China sows. *American Breeders Report* **3**.

VARIATION AND INHERITANCE IN SIZE IN TRYPANOSOMA LEWISI[1]

1. Life-cycle in the Rat and a Study of Size and Variation in "Pure Line" Infections[2]

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Communicated by R. Pearl, May 2, 1921

The flagellate, Trypanosoma lewisi, is a non-pathogenic blood parasite occurring in various species of rats all over the world. It is known to be transmitted from rat to rat by the rat flea. This trypanosome was selected for the present work because it occurs in the latitude of Baltimore and the vertebrate and invertebrate hosts can easily be reared in the laboratory.

The general plan of the present work on size in T. lewisi is to make a careful study of size and variability in a pure line and then with this background to attempt to explain the facts observed in infections occurring in nature. After a pure line infection was obtained the following questions were attacked: (1) What are the mean and the coefficient of variation? (2) Does growing the same "pure line" in different vertebrate hosts cause significant differences in the mean size or in the coefficient of variation? (3) Does passage of the "pure line" through the invertebrate host cause significant differences in the mean or coefficient of variation? This question gives us a chance to test the possibility that passage of the "pure line" through the invertebrate host may cause a splitting up of the "pure line" into heritably diverse lines. After a study is made of these questions we can attack the final one: (4) Does an infection occurring in nature consist of a large number of "pure lines" such as has

been described by Jennings[3] and others in free-living protozoa which differ among themselves but are *per se* constant in size? As will be seen later, these questions cannot be approached with any degree of exactness until a thorough study is made of the changes in mean size and variability throughout the course of an infection. The present paper deals with these changes in size and variability and with the first of the questions enumerated above. The other three questions are to be taken up in a later report.

A study of inheritance in a parasitic protozoon such as T. lewisi is of interest from several points of view. In the first place the results are of interest from a comparative standpoint when considered in the light of recent advances in our knowledge of the genetics of free-living species. In the second place, the results may be of value in the interpretation of the results of the many studies on the production of strains of parasitic organisms which exhibit new characteristics. Finally the work is the first of a program of investigations, the ultimate object of which is a study of the mechanism of the formation of new lines exhibiting such characters as arsenic-fastness and the inheritance of these characters after passage through both the vertebrate and the invertebrate hosts.

While lack of space prevents a discussion of technique in detail, it may be noted that every precaution was taken to use microscopical technique such that the trypanosomes would be free from shrinkage and distortion. All measurements were made from camera lucida outlines drawn at a magnification of ×3000. The unit used in measuring the drawings was 3 mm.; consequently all of the determinations given in this paper are in actual microns. In making the determinations 100 specimens, taken at random without selection, were drawn in each case. In isolating single organisms with which to start "pure line" infections, a sensitive mercury pipette was used in conjunction with a Barber pipette holder. Figure 1 is a diagram of a trypanosome indicating the various parts of the organism and the distances measured in this work. The names of the parts of the trypanosome run vertically and the abbreviations of the six distances run horizontally.

Size and Variation throughout a "pure line" Infection.—The infection in the rat can be divided into three periods: (1) the incubation period lasts from 1–7 days and is the time which elapses between inoculation and the first appearance of the trypanosomes in the blood. (2) The multiplication period starts with the first appearance of the trypanosomes in the blood and lasts for 10–25 days. This period is characterized by the great variations in size due to the growth and the multiplication of the trypanosomes. (3) The period of "adult" infection follows the second period and is characterized by the absence of all growth and multiplication. This period lasts from one to many weeks at the end of which time the trypanosomes disappear from the blood and the rat is

immune to another infection with T. lewisi. It is apparent that in an organism which shows a cycle of growth and division such as characterizes T. lewisi, we must make all comparisons of size and variability at the same stage in the cycle, and that if there is a period in which there is no growth and division comparisons should be made during this period.

A study of the changes in the means and in the coefficients of variation of the different parts of the trypanosome throughout the course of a "pure line" infection demonstrates very clearly that there are different periods of the infection and indicates the stage at which to make comparisons of size and variability between different infections. Let us take, for example, the coefficients of variation and the means for total length in rats 116 and 105 which are shown in figure 2. The infection in rat 116 was started from a single trypanosome and rat 105 was inoculated from rat 116. In other words, although the infection in the first rat started from a single specimen and in the second rat from many specimens, all of the trypanosomes in both rats are descendants of the single organism injected into rat 116. We can make no determinations during the incubation period since no one knows where the organisms are at this time. Let us consider first the constants for rat 105. On the first day of the blood infection the mean length was $24.785 \pm .423$. This rose rapidly until the 5th day when it reached $30.108 \pm .280$. This rise continued gradually until it reached $31.412 \pm .065$ by the 19th day. From the 19th until the 32nd day, at which time the infection disappeared from the blood, there was no significant change in the mean. The coefficient of variation behaved in much the same manner as the mean. On the first day of the infection it was $26.52 \pm 1.35\%$. It dropped very rapidly for the first seven days and then much slower for the next twelve days. By the 19th day it reached the low value of $3.11 \pm .14\%$ and it showed no significant change from this value throughout the remainder of the infection.

It is well to compare the conditions found in rat 116 with those in rat 105. Rat 116 is given here because a longer time elapsed before the infection reached the adult stage than was the case in any of the other infections studied. This is due probably to the fact stated above, viz., that the infection in rat 116 started from a single trypanosome while the others although they were "pure lines" were sub-inoculated from 116, and in consequence were started with a large number of specimens. As these curves are probably expressions of the resistance of the host to the parasite, we would expect that this resistance would increase more rapidly when the infection is started with a large number of trypanosomes than when it is started with only one. We cannot compare the shape of the curves in the two rats very well because there are not enough points in the curve for rat 116. One thing is probably true, however, and that is that both the mean and the coefficient of variation reach a constant

value by the 25th day. At first it looks as if the mean tends to rise even until the 32nd day. That this is not the case, however, is shown by the fact that the value on the 25th day does not vary appreciably from that of the 72nd day.

The same type of result was obtained for all of the six distances shown in figure 1, namely, for the distances posterior end *to* parabasal body, parabasal body *to* nucleus, nucleus *to* anterior end, anterior end *to* end of

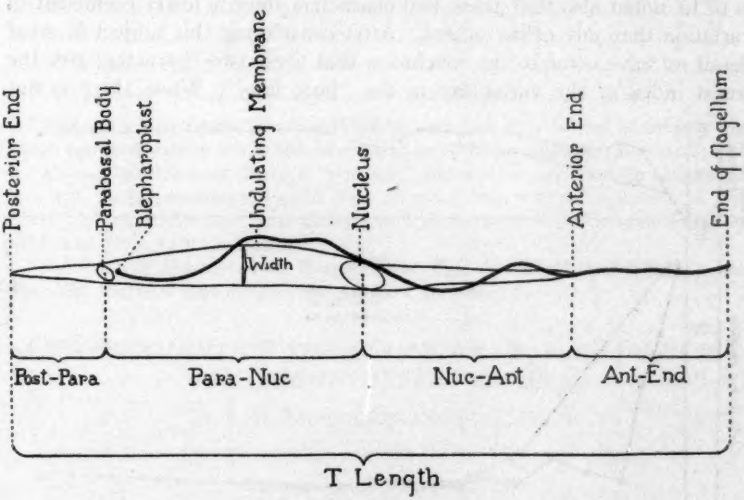

FIG. 1

Diagram of T. lewisi showing the parts of the organism and the distances measured in this work. The parts of the organism are placed vertically while the distances are placed horizontally. The latter consist of the distance from (1) posterior end to parabasal body, (2) parabasal body to nucleus, (3) nucleus to anterior end, (4) anterior end to end of flagellum, (5) total length, and (6) width.

flagellum, and width, although most of the constants do not reach as low a level as is the case with those for total length (see table 1). Curves of this nature were obtained in four rats. These results prove, what we had been led to believe from cytological evidence, viz., that there is practically no division or growth in T. lewisi after the 25th day of the blood infection.

After it was determined that there was no significant change in the mean or coefficient of variation after the 25th day we decided to make all measurements after this day. Most of the measurements which will be given in a later report were made on the 30th day of the blood infection. The fact that the trypanosomes in the blood of the rat reach what we can consider an adult stage makes size a very favorable character with

which to work. It affectively eliminates growth factors from our computations.

The most interesting feature in the study of the variability exhibited by the "pure line" is that once the organism has reached the adult stage of infection the coefficients of variation are extremely low. Table 1 shows the constants for rat 105. The coefficients of variation for total length and parabasal-nucleus are 2.80% and 2.21%, respectively. It is to be noted also that these two characters show a lower coefficient of variation than any of the others. After considering this subject in great detail we have come to the conclusion that these two characters give the truest index of the variability in the "pure line." While there is not

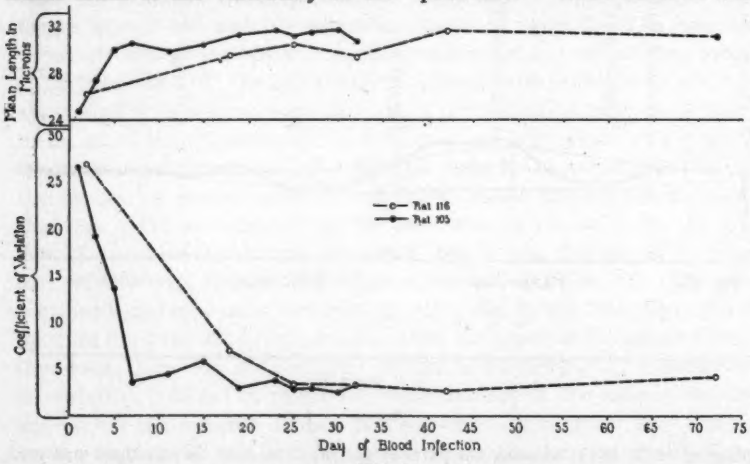

FIG. 2

Graph showing the changes in the mean and coefficient of variation for total length in rats 116 and 105. The infection in 116 was started from a single organism and 105 was inoculated from 116. The trypanosomes disappeared from the blood of rat 105 on the 32nd day and from 116 on the 72nd day.

much doubt that posterior-parabasal is more variable than either of these two, we feel that much of its variability as well as that of the other distances with high coefficients is due to the difficulty of making the measurements.

Conclusion.—We can draw the following conclusions from this part of the work: Trypanosoma lewisi reaches an "adult" stage in its development in the rat in about 25 days after it appears in the blood. Once this stage is reached there is practically no division or growth. Due to the elimination of growth factors, the organisms show a very low coefficient of variation in "pure line" infections, provided they are measured after the "adult" stage is reached. These facts make T. lewisi a very favorable organism in which to study size and variation.

TABLE 1

CONSTANTS FOR THE SIX DISTANCES GIVEN IN FIGURE I FOR THE "PURE LINE" IN RAT 105 ON THE 25TH DAY OF BLOOD INFECTION. THE MEANS AND STANDARD DEVIATIONS ARE IN MICRONS

	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION
Post-Para	$4.268 \pm .036$	$.544 \pm .025$	$12.74 \pm .61$
Para-Nuc	$10.854 \pm .016$	$.240 \pm .011$	$2.21 \pm .10$
Nuc-Ant	$9.511 \pm .047$	$.704 \pm .033$	$7.41 \pm .35$
Ant-End	$6.619 \pm .068$	$1.010 \pm .048$	$15.27 \pm .74$
T. Length	$31.251 \pm .059$	$.875 \pm .041$	$2.80 \pm .13$
Width	$1.590 \pm .015$	$.230 \pm .010$	$14.47 \pm .70$

[1] This and a later report form a preliminary account of a series of investigations which are being carried out in this laboratory on variation and inheritance in T. lewisi.

[2] Throughout this work the term "pure line" infection has been used to designate an infection, the trypanosomes of which have all arisen from a single organism. A given "pure line" may either have been started from a single specimen or it may have been sub-inoculated from such an infection.

[3] See especially Jennings, H. S., *Proc. American Phil. Soc.*, **47**, 1908 (393–546). *American Nat.*, **43**, 1909 (321–337). *Ibid.*, **45**, 1911 (79–89).

MEASUREMENT OF THE DIAMETER OF ALPHA-ORIONIS BY THE INTERFEROMETER

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Communicated March 12, 1921

It was shown in these PROCEEDINGS[1] that in the application of interference methods to astronomical measures, the fringes show no decrease in visibility with the slits separated by the full aperture of the 100-inch Hooker telescope even when the seeing is poor. It was therefore decided to build an interferometer with movable outer mirrors in order to test for separations as great as 20 feet.

The interferometer bed consists of a fabricated steel beam, designed with special regard to lightness and stiffness, mounted on the end of the Cassegrain cage of the 100-inch reflector (fig. 1). Two tracks were planed on the top, true to 0.001 inch (0.025 mm.), the frame being supported on the planer as it was to be mounted on the telescope. On this beam are mounted four slides, each carrying a mirror about 6 inches (152 mm.) in diameter, inclined 45 degrees to the base. The two inner mirrors M_2, M_3, are fixed, 45 inches (114.2 cm.) apart, while those of the outer pair M_1, M_4, are movable and can be separated to a distance of 20 feet (6.1 m.). The light pencils are reflected from the outer to the inner mirrors, thence over the customary path a, b, c, d, in the telescope, and are viewed with an eyepiece at the Cassegrain focus d, where the equivalent focal length is 134

feet (40.8 m.). The fixed position of the inner mirrors gives a constant fringe spacing equal to 0.02 mm., which is easily visible with a power of 1600.

Coincidence of the two interferometer pencils at the focus is produced by adjusting the inner mirrors during the day and the outer mirrors on a star at night. Equality of path is obtained by placing the outer mirrors symmetrically on the beam, as nearly as possible, and then adjusting a double wedge of glass lying two feet within the focus in the path of one of the pencils.

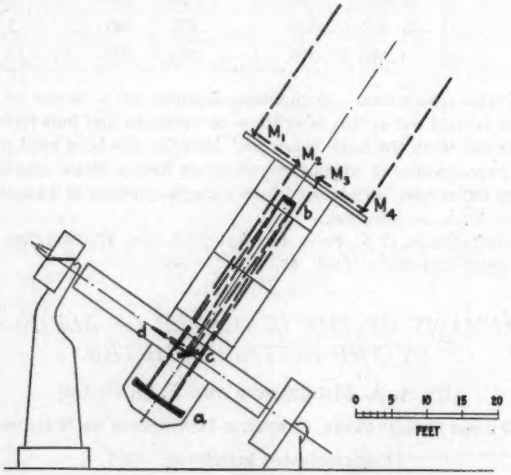

FIG. 1

Compensation for the mean thickness of the wedges is made with a plate of plane-parallel glass placed in the other pencil.

One of the wedges is fixed, the other is adjustable in a direction parallel to the inclined surfaces, a linear motion of 1 millimeter introducing an equivalent air path of about 0.09 mm. Fringes can be observed throughout a linear motion of the wedge amounting to 0.16 mm., corresponding to about 26 light waves. This range can be increased by introducing a direct-vision prism behind the eyepiece.

For comparison purposes a series of reference or "zero" fringes is obtained in the eyepiece by covering the end of the telescope tube completely save for two apertures in the beam (in addition to those of the inner mirrors) 6 inches in diameter.

When the interferometer is in perfect adjustment and the outer mirrors are close together, two separate star images are seen in the eyepiece, one formed by light reflected by the mirrors, the other by light admitted by the supplementary apertures which produce the zero fringes. Each image is surrounded by diffraction rings and crossed by the interference fringes,

which appear as straight lines, alternately dark and light, perpendicular to the line joining the mirrors.

As the outer mirrors are separated, the visibility of the zero fringes remains constant, while that of the interferometer fringes gradually decreases until a point is reached where the latter vanish; as the mirrors are further separated the interference fringes should reappear, approach a secondary maximum, and again disappear, this phenomenon being repeated indefinitely.

We are interested chiefly in the first disappearance. The distance between the mirrors corresponding to extinction is the observed quantity required to determine the angular diameter of the star. Thus far it has been necessary to move the mirrors by steps, as screws are only now being installed to maintain the mirrors at equal distances.

The visibility of fringes obtained with the interferometer pointed on Vega in August, 1920, with the mirrors separated 18 feet (5.5 m.), was fully as great as with the mirrors 6 feet (1.83) apart, thus indicating that atmospheric conditions will easily permit the use of even greater separations.

Calculations of stellar diameters based on estimates of surface brightness made by Eddington, Russell, and Shapley, indicated that α Orionis, because of its relatively large diameter, would be a promising object to attempt to measure with the 20-foot interferometer. Merrill first examined the star with the apparatus used by Anderson[2] in the measurement of Capella and found a definite decrease in visibility for the maximum separation of the slits (100 inches). This was true for all position angles, thus indicating that the star was not a binary.

On December 13, 1920, the interferometer was tested by Pease on β Persei and then on γ Orionis. Both stars are known to have diameters much smaller than can be measured with this instrument. When adjusted with the mirrors separated 121 inches (229 cm.), both the zero and the interferometer fringes appeared in the eyepiece. When the instrument was directed to α Orionis the interferometer fringes could not be found. α Canis Minoris was then observed and the interferometer fringes were easily seen thus indicating that the instrument was still in adjustment. It is thus clear that the disappearance of the fringes for α Orionis was real and not due to any disturbance of the mirrors, for the seeing was good and any flexure changes involve only a very slight shift of the compensating wedge to bring the fringes into view again.

On December 14 and the nights following, the seeing was poor and as the visibility of the zero fringes was decidedly lower than on the night of the 13th, no attempt was made to work on α Orionis. With a mirror separation of 13 feet attention was directed to α Ceti, α Tauri and β Geminorum. The zero fringes were seen in every case, though much reduced in visibility, but as the interferometer fringes could not be seen at all except at intervals of better seeing, it is presumed that there was an actual de-

crease in visibility and that with further observation some estimate can be made of the diameter of these stars.

Assuming that the effective wave-length of α Orionis is 5.75×10^5 cm. and that the value of d is 121 inches (306.5 cm.), the angular diameter of α Orionis from the formula $\alpha = 1.22\frac{\lambda}{d}$ proves to be 0.047. An estimate of its linear diameter may be made by using a mean parallax of 0".018,[3] which gives a diameter of 240×10^6 miles, or slightly less than that of the diameter of the orbit of Mars.

Corrections to this value will be derived by an experimental determination of the value of λ for this particular star; by a more accurate setting of the mirrors, for the uncertainty of this measure is at least 10 per cent; and by further determination of the parallax. The angular value given above is that corresponding to a uniformly illuminated disk. A darkening toward the limb, equal to that of the sun, would require an increase in the diameter of about 17 per cent.

We wish to express our obligations to Director Hale both for his encouragement and for placing the resources of the observatory at our disposal, and to Mr. J. A. Anderson for his checking of the measures on the night of December 13.

[1] These PROCEEDINGS, 6, 1920 (474–475).

[2] *Mount Wilson Contributions*, No. 185; *Astroph. J. Chicago*, 51, 1920 (263–275).

[3] The weighted mean of Adam's spectroscopic parallax, 0.012 and the trigonometric parallaxes of Elkin, 0.030, and Schlesinger, 0.016.

AN OVERLOOKED INFINITE SYSTEM OF GROUPS OF ORDER pq^2

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Communicated April 28, 1921.

The determination of all the possible abstract groups of order pq^2 p and q being distinct prime numbers, was considered by Cole and Glover in an article published in the *American Journal of Mathematics*, vol. 15 (1893), p. 191 and by O. Hölder in a long article published in the *Mathematische Annalen*, vol. 43 (1893), p. 301. In a subsequent article, published in volume 46 of the latter journal, Hölder directed attention in foot-note on page 323 to the fact that the enumeration of these groups contained in the former of the two articles mentioned above was incomplete.

The main object of the present article is to establish the fact that there is an infinite system of abstract groups of order pq^2 which was overlooked not only by the authors already mentioned but also by others, including W. Burnside who gave an incomplete list of these groups in both editions of his well known and meritorious work entitled, "Theory of Groups of

Finite Order" 1897 and 1911. The system of groups in question consists of $q-1$ distinct groups for all values of p and q which satisfy certain conditions to be noted later while only one such group is given in the published lists. This system of groups is also interesting in view of the fact that each group of the system contains q characteristic operators including the identity.

To construct the groups of the system in question suppose that q is a divisor of $p-1$ and establish a simple isomorphism between q cyclic groups of order pq written as regular substitution groups. Let t represent the substitution of order q which permutes the corresponding letters of these q cyclic groups so that t is commutative with each of its substitutions and together with the cyclic group of order pq formed by the given isomorphism generates a regular abelian group of order pq^2. Let $S_1 S_2 \ldots S_q$ be substitutions of order q and of degree $pq-q$ which transform corresponding generators of the given cyclic groups of order pq into the same power belonging to exponent q modulo pq and so chosen that the product $S_1 S_2 \ldots S_q$ is commutative with t. Finally let S_0 represent a substitution of order q contained in the first one of the q given cyclic groups of order pq.

The product $S_0 S_1 S_2 \ldots S_q t$ is a substitution of order q^2 whose q^{th} power is the substitution of order q, in the group formed by means of the said isomorphism, whose constituent is S_0. Hence it results that the pq substitutions of the group of order pq^2 thus constructed which transform into a given power belonging to exponent q modulo pq a generator of the given cyclic group of order pq can be so chosen that their q^{th} power is an arbitrary operator of order q contained in this cyclic group. The totality of these pq substitutions must correspond to itself in every automorphism of this group of order pq^2. Hence this q^{th} power must be a characteristic operator of the group.

From the preceding paragraph it results that each of the groups of order pq^2 under consideration contains q characteristic operators including the identity and that any of these operators which is of order q can be made the q^{th} power of all the pq operators of the group which transform the operators of order p in the group into a particular power. Hence there are $q-1$ distinct groups for particular values of p and q which satisfy the conditions that p and q are such primes that $p-1$ is divisible by q. These $q-1$ groups are conformal: that is, they contain the same number operators of each order. It is well known that for any prime number of q there is an infinite number of prime numbers p such that $p-1$ is divisible by q and hence there is no upper limit to the number of such distinct conformal groups.

The smallest order for which there exist at least two such conformal groups is 63. In this special case one of the characteristic operators of order 3 is the third power of the operators of order 9 which transform the operators of order 7 into their fourth powers while the other operator of order 3 is the third power of those which transform the operators of

order 7 into their squares in one of the two conformal groups. In the other group the reverse is true. Hence it is not possible to establish a simple isomorphism between the operators of these two groups. In view of the elementary properties of these groups it appears strange that the wide-spread error noted above was not corrected for more than a quarter of a century, especially since the incorrect results obtained by O. Hölder have been used by various writers in extending his work.

THE GLOBE, A SIMPLE TRISOMIC MUTANT IN DATURA

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Communicated by C. B. Davenport, March 10, 1921

In a series of articles already published,[1, 2, 3] or at the present writing in press (*American Naturalist*, *Genetics*), a number of recurrent mutants discovered in the Jimson Weed (*Datura Stramonium*) have been described and their peculiarities in external appearance shown to be connected with the presence of one or more extra chromosomes in their nuclei. Evidence has been presented which indicates that a given mutant of the "simple trisomic" type is conditioned by the presence of a single extra chromosome in a specific one of the 12 chromosomal sets. Such a form is called a simple trisomic mutant since in its somatic nucleus one of the 12 sets is a trisome with three homologous chromosomes instead of all the sets being disomes with two chromosomes each. The presence of an extra chromosome in a specific chromosomal set not only causes specific peculiarities in the growth and appearance of the mutant which results, but also brings about peculiarities in the inheritance of the mutant complex.

It is the purpose in the present paper to summarize the findings in regard to one of the simple trisomic mutants—the Globe—in anticipation of a more detailed paper to be published shortly in *Genetics*. The data were accumulated for the most part before the chromosomal condition in the Globe and other simple trisomic mutants had been determined by my colleague, Mr. John Belling, from studies of mitotic figures in the pollen mother cells.

The Globe was the first mutant recognized in the Jimson Weed, having been discovered in 1915. Its depressed globose capsules suggested the name. Its adult characters as well as the broad entire leaves of its seedlings render the Globe one of the easiest mutants to recognize at any stage of development. It is the only one in fact that we have been able to pick out readily in the seed pan. Since usually it has not been necessary to grow plants beyond an early seedling stage when it is desired to distinguish Globes from normals, it has been possible with this mutant to base conclusions on a larger number of individuals than could readily have been obtained if we had been dealing with the other mutant forms.

The Globe mutant differs from normals apparently in all parts of the plant. It shows a complex of characters readily recognized, whether the plants in question have purple or white flowers, many or few nodes, and spiny or smooth capsules. Globes, like other mutants of this type, are slower in growth than normals; and in competition with normals are liable to be crowded out by them.

TABLE 1

GLOBES SELFED AND CROSSED RECIPROCALLY WITH MAIN LINE NORMALS. PLANTS POLLINATED IN GREENHOUSE, 1916–17. RECORDS TAKEN IN SEED PANS IN GREENHOUSE, 1917–18

ORIGIN OF SEED	SEEDS PARENTS	SEEDS PLANTED	SEEDLINGS	PER CENT SEEDLINGS	GLOBES	NORMALS	PER CENT GLOBES	RATIO G:N
Globe Selfed	27	3015	1782	59.10	400	1382	22.45±0.676	1:3.46
Globe x Normal	27	2628	1935	73.63	500	1453	25.84±0.671	1:2.87
Normal x Globe	27	2771	1812	65.39	53	1759	2.92±0.269	1:33.19

Percentage difference between offspring from Globe Selfed and from Globe x normal $=3.39 \pm 0.935$. Diff./E. Diff. $= 3.59$.

Early breeding work with the Globe indicated that the manner of its inheritance was not in accord with any simple Mendelian interpretation. A more extensive series of selfs and crosses was therefore carried out in order to determine more accurately the extent to which the Globe complex could be transmitted. In table 1 is presented a summary of the experiment. In this table are given the number of seeds planted and the percentage of recordable seedlings which they produced. It is obvious that a difference exists between the inheritance through the male and that through the female parent. The egg cells of Globes, whether fertilized by Globe pollen or by pollen from normal plants, transmit the Globe complex to only about 25 per cent of the offspring. Globe pollen, when used on normal plants, transmits the character to only about 3 per cent of the offspring This figure, though small, is too large to be accounted for by the occurrence of new Globe mutations, in view of the rarity of Globes from normal parents in comparable material. The normal offspring of Globes seem to be true normals so far as their breeding behavior is concerned.

If 3 % represents the average number of Globe pollen grains which transmit the mutant character, we should expect a higher proportion of Globe offspring when Globe pollen is used than when pollen from normals is used on Globe females. The reverse, however, is actually the case, and Globes selfed produced a lower percentage of mutant offspring than Globes pollinated by normals. The explanation may possibly be connected with a difference in vitality between seedlings produced by self and those produced by cross pollination. The fact is at least suggestive that a lower per-

TABLE 2

MAIN LINES AND OCCURRENCE OF NEW GLOBE MUTATIONS FROM 1915 TO 1920. THE FIRST MUTATION FOUND IN 1915 IS NOT INCLUDED. UNDER "TYPE," "P" STANDS FOR THE MENDELIAN CHARACTER PURPLE AND "W" FOR WHITE, "AR" FOR ARMED CAPSULES AND "IN" FOR *Inermis*, "M" FOR MANY NODES AND "F" FOR FEW NODES

NO.	TYPE	ORIGIN	SEED PARENTS	NOR.	GL.	% GLOBES
1	Par M	Washington, D. C.	50	3313	6	0.181 ± 0.005
2	War M	Washington, D. C.	19	1292		
3	War F	Erfurt, Germany	9	854		
4	Win F	Erfurt, Germany	20	1479		
5	Par M	Staten Island, N. Y.	17	933		
6	War M	Staten Island, N. Y.	35	1462		
7	War M	Bronx, N. Y.	13	1186		
8	War M	Woodbury, N. Y.	7	377		
9	Par M	Cold Spring Harbor, N. Y.	13	844	2	0.236 ± 0.112
10	Par M	Charlotte, Va.	5	394		
11	Par M	Danville, N. C.	6	595		
12	War M	Lloyds Neck, N. Y.	1	92		
13	War F	J. L. Childs	6	625		
14	War F	Naples, Italy	6	627		
15	Par M	D. Stramoinum gigantea	5	408		
16	Par F	D. Leicharti	5	370		
17	Win F	D. Laevis	5	701		
18	Par M	D. Ferox	5	400	1	0.249 ± 0.168
19	War F	D. Quercifolia	7	653		
Totals—Main Lines Inbred			234	16605	9	0.054 ± 0.012
F_1's			159	7086	3	0.042 ± 0.016
Back crosses			57	2064		
Extractives			215	12353	12	0.091 ± 0.018
Totals—Crosses and Extractives			431	21503	15	0.070 ± 0.012
Grand totals			665	38108	24	0.063 ± 0.009

centage of recordable seedlings was obtained when Globes were selfed than when they were crossed with normals.

Simple trisomic mutants produce dimorphic gametes with 12 and 13 chromosomes instead of gametes with uniformly 12 chromosomes as is characteristic of normals. Two types of egg cells should be produced in equal numbers and, on the assumption that in general only pollen grains with 12 chromosomes are able to assist in fertilization, an equal number of Globes and normals should appear in the offspring of Globes. That mutants and normals are not thrown in equal numbers is probably due to the weaker vigor of the mutant zygotes.

From the foregoing, it is concluded (*a*) that the mutant complex is transmitted primarily through the egg cells and (*b*) is transmitted not at all or only to a slight extent through the pollen; (*c*) that the deviation in the offspring from an equality of Globes and normals is due to the lessened vitality of the mutant forms; (*d*) that the higher percentage of Globes obtained by crossing Globes with normals, over selfing, is due to an increased vigor brought about by the cross.

Simple trisomic mutants are characterized by a considerable proportion of defective pollen grains. The Globe has about 8 per cent bad grains

TABLE 3

OCCURRENCE OF NEW GLOBE MUTATIONS FROM MUTANT PARENTS

	MUTANT SELFED SEED				MUTANT X NORMAL SEED				NORMAL X MUTANT SEED			
PARENT	PAR.	NOR.	GLOBES	% GL.	PAR.	NOR.	GLOBES	% GL.	PAR.	NOR.	GLOBES	% GL.
Poinsettia	11	968	4	0.41	5	389	1	0.26	3	591	1	0.17
Poinsettia var. Wiry	2	189	0		1	15	0		1	225	1	0.44
Cocklebur	20	1859	1	0.05	8	1047	1	0.10	6	1167	0	
Ilex	8	855	0		5	538	1	0.19	4	975	0	
Mutilated	16	871	1	0.11	8	351	0		4	552	2	0.36
Sugar Loaf	8	413	1	0.24	3	367	0		1	197	0	
Rolled	8	705	1	0.14	2	222	4	1.80	1	245	1	0.41
Reduced	6	707	2	0.28	1	127	1	0.78	1	215	0	
Buckling	8	856	1	0.12	1	106	0		1	246	0	
Glossy	7	897	1	0.11	1	143	0		1	253	0	
Microcarpic	18	994	1	0.10	5	178	0		4	353	0	
Spinach	13	625	8	1.26	3	187	4	2.09	2	377	0	
Totals	125	9939	21	0.211 ±.031	43	3670	12	0.326 ±.064	29	5396	5	0.093 ±.028

Percentage difference between offspring from mutant selfed and mutant x normal = 0.115 ± 0.071. Diff./E. Diff. = 1.62.

Percentage difference between offspring from mutant x normal and normal x mutant = .233 ± .070. Diff./E. Diff. = 3.33.

which is the lowest average for any of the Datura mutants of this type yet investigated. Normal plants show only about 2.7 % of defective grains.

Before the cause of the Globe mutation was discovered, an attempt was made to increase by selection the proportion of Globes in the offspring of selfed Globe parents. Globes were accordingly inbred for ten generations but the proportion of mutants and normals in the offspring was not noticeably affected.

Inasmuch as the Globe is one of the most readily recognized of all the Datura mutants and has been sought for in our cultures since its first appearance in 1915, it is possible to give more reliable figures in regard to the frequency of its new appearance than could be done for the mutants discovered later. In table 2 is summarized the occurrence of Globe plants in offspring from selfed parents of the 19 different main lines. The various lines have the color, spine and node characters indicated in the table. It is seen that new Globe mutations have occurred in all the lines considered together in about 0.05% of the offspring which is about one out of 2000 individuals. The offspring from crosses between main lines have shown new Globe mutations in about the same proportion as in the main lines themselves.

We have just discussed the occurrence of Globe mutations from normal parents. It will be of interest to consider the occurrence of this mutant from parents belonging to the other mutant forms. In table 3 are shown

the percentages of new Globes that have occurred from selfing the various mutants and from crossing them reciprocally with normals. The percentage of Globes appears to be somewhat higher than from the main line parents. It is of interest to note that when mutants are used as males in crosses with normals, the percentage of Globe mutations is reduced to about the average expected from the assemblage of main line parents. A comparison of table 3 with table 1, however, will be instructive and lead us to the conclusion that the egg cell is not only more effective in transmitting the mutant character, once it has arisen, but is also more effective in originating these mutations than is the pollen grain.

[1]Blakeslee, A. F. and B. T. Avery, *J. Heredity*, **8**, 1917 (125–131).
[2]Blakeslee, A. F. and B. T. Avery, *Ibid.*, **10**, 1919 (111–120).
[3]Blakeslee, A. F., John Belling and M. E. Farnham, *Science, N. S.*, **52**, 1920 (388–390).

STUDIES OF MAGNITUDES IN STAR CLUSTERS XIII. VARIABLE STARS IN N. G. C. 7006

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Communicated by G. E. Hale, March 22, 1921

The faintest and most distant variable stars on record have been found on photographs of the globular cluster N. G. C. 7006 made with the 60-inch and 100-inch reflectors at Mount Wilson. The new variables are of considerable value in measuring the size of the galactic system, because they are members of one of the remotest stellar groups now known and serve to determine its distance and dimensions.

The position of the cluster for 1900.0 is:

$$\text{R.A.} = 20^h\,56^m.8, \quad \text{Decl.} = +15^\circ\,48'$$

Its galactic coördinates are:

$$\beta = -20^\circ, \quad \lambda = 32^\circ$$

and its apparent diameter on the Franklin-Adams charts is three-fourths of a minute of arc.

By the usual photometric methods for determining the distances of globular clusters, the parallax of N. G. C. 7006 has been estimated to be:

$\pi = 0''.000015$, from the parallax-diameter correlation.[1]
$\pi = 0.000014$, from photographic magnitude of brightest twenty-five stars.[2]
$\pi = 0.000016$, from photovisual magnitude of brightest thirty-eight stars.[3]
$\pi = 0.000016$, from integrated visual magnitude.[4]

The foregoing accordant results make it fairly certain that N. G. C. 7006 is somewhat more distant than any other globular cluster in the present lists;

but it is now possible with the aid of the variable stars to determine the distance much more accurately.

The following photographs of the cluster have been examined in the stereocomparator for the detection of variable stars.

TABLE 1

PLATE No.	PLATE Kind	DATE	TELESCOPE	EXPOSURE TIME
4168	S27	1917 Nov. 10.387	60-inch	15m
5168a*	S30	1919 Dec. 24.284	60-inch	30
5402	S30	1920 July 16.622	60-inch	70
5500	S30	1920 Aug. 10.515	60-inch	50
P 9	S30	1920 Sept. 11.428	100-inch	30
P 23	S30	1920 Sept. 12.381	100-inch	40
P 29	S30	1920 Sept. 12.556	100-inch	30
5601	S30	1920 Sept. 14.312	60-inch	45
P 50	S30	1920 Sept. 15.379	60-inch	60

*Plate 5168a was made by Mr. Hoge, the others by Mr. Shapley.

TABLE 2

STAR	X	Y
1	−177″.6	+113″.8
2	−38.0	−38.0
3	−27.6	+32.8
4	−24.2	−42.2
5	−24.2	+36.2
6	−15.5	−44.8
7	0.0	−38.0
8	+31.0	+13.8
9	+36.2	+15.5
10	+38.0	−13.8
11	+141.4	+48.3

Seven of the eleven variables found on the above plates show conspicuous variation in the course of one night, and the other four appear also to be short period variables. In magnitude and range they are very much alike, and in this cluster, as in Messier 3, ω Centauri and other systems, the variables are between one and two magnitudes fainter than the brightest stars. It is probably safe to assume, therefore, that these faint variable stars are typical short-period Cepheids, similar to those commonly found in globular clusters.

The coördinates of the variable stars, referred to the center of the cluster, are given in seconds of arc in table II. Nos. 2 and 5 were found or suspected by Miss Ritchie, the others by Miss Mayberry.

From fifty-three measures of the brightness of the eleven variable stars on the plates made with the 60-inch reflector, a median magnitude of 18.96 is found. The median for the seven that appear most certainly to be short period Cepheids is also 18.96. The photographic magnitudes[4] of the variables are based on the results for the bright stars of the cluster, published in *Mt. Wilson Contr.*, No. 156, p. 4, 1918.

The observed range in photographic magnitude for the eleven variables is 0.83; for the seven variables it is 0.99.

If we adopt from *Mt. Wilson Contr.*, No. 151, the value −0.23 as the median photographic absolute magnitude of short period Cepheids, we have $m - M = 19.2 = 5 (\log d - 1)$, from which the distance, d, is found to be 69,000 parsecs. Expressed as a parallax, this is 0″.0000145—a highly satisfactory confirmation of the former results.

Although N. G. C. 7006 is the smallest known cluster in angular diameter, its linear dimensions are comparable with those of Messier 13. The di-

ameter probably exceeds 300 light years, since two of the variables are more than 170 light years distant from the center of the cluster.

It is of interest to recall that the study of the brightest stars in N. G. C. 7006 has shown no effect of selective scattering of light in space. It also appears, from the agreement of the parallax based on angular diameter with the values based on magnitude methods, that the general non-selective absorption of light is inappreciable in the direction of N. G. C. 7006, even when the distance involved is, as in this case, 225,000 light-years.

[1] *Mt. Wilson Contr.*, No. 152. p. 13, 1917; *Astroph. J. Chic.*, **48**, 1918 (166).
[2] *Mt. Wilson Contr.*, No. 152, p. 14, *n*-l, 1917; *Ibid.*, **48**, 1918 (167).
[3] *Mt. Wilson Contr.*, No. 156, pp. 1–6, 1918; *Ibid.*, **49**, 1919 (249–54).
[4] *Mt. Wilson Contr.*, No. 161, pp. 16–18, 1918; *Ibid.*, **50**, 1919 (122–4).

THE SKIN TEMPERATURE OF PACHYDERMS

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Read before the Academy, April 26, 1921

A knowledge of the temperature of the skin is of great assistance in interpreting the laws governing the loss of heat from the animal organism, but with warm-blooded animals, such as birds and many mammals, the skin temperature is determined only with difficulty, because of the covering of hair or fur. With humans, also, the protective clothing interferes with the accurate determination of skin temperature, for numerous observations have shown that even under ordinary clothing the skin temperature of man is by no means constant and, due to the protective covering, is undoubtedly much higher than it would otherwise be. It seemed, therefore, that records of the skin temperature of certain hairless animals would be of value, since the factor of covering would thus be eliminated. Accordingly, we took advantage of the excellent material at the New York Zoological Park and of the friendly coöperation of Mr. Raymond L. Ditmars to make such observations, and as a result are able to report the surface temperatures of two elephants, one rhinoceros, and a hippopotamus, all presenting large hairless surface areas.

The method employed was that described in an earlier communication.[1] The apparatus consists of two copper-constantan thermo-junctions, with special means of application to the skin to secure the true skin temperature rather than the resultant of skin and environmental temperature. One junction is kept in a thermos bottle with a carefully calibrated thermometer, which is read practically every minute or two, and the other junction applied to the skin. The difference in temperature between the two junctions is noted on a galvanometer, whose "constant" is likewise checked every few minutes.

The natural inquisitiveness and restlessness of the elephants made the task of recording the skin temperature somewhat trying, although in no sense hazardous. The rhinoceros presented an unexpectedly favorable opportunity for measurement, while the uncertain temperament of the hippopotamus interfered greatly with the securing of records of his temperature. An especially advantageous feature of this series of observations is the fact that the temperature of the environmental air in the elephant house at the New York Zoölogical Park remains relatively constant at about 19.5° Centigrade, night and day.

Excluding records obtained at partially protected points, such as the back of the ear, the groin, and axilla, we found with a female Indian elephant a range in skin temperature from a minimum of 20.8° C. at a position on the forehead, midway between the two eyes, to a maximum of 29.6° C. on the shoulder. With a male African elephant the range was from 21.4° to 28.3° C. The relation between surface temperature and the distribution of the blood was strikingly evident in the temperature records on the ear, on the back side of which the veins are very readily observable. Near the veins the skin temperature was high. Owing to the cracks and crevices in the thick elephant skin, difficulty was at times encountered in securing records of surface temperature, especially on the sides of the body, since the tendency was for the warm air to rise, with a distinct circulation of air through the cracks in the skin. Every attempt was made to use as smooth a piece of skin as possible for the temperature measurements. The elephant, therefore, exposed to an environmental temperature of approximately 19.5° C., had a skin temperature which averaged not far from 25.5° C. While there were rather large differences at times between the two elephants, the general picture showed a reasonably uniform bilateral temperature distribution.

The rectal temperature of elephants has not been frequently reported. Dr. W. R. Blair of the New York Zoölogical Society found in his measurements that the rectal temperature of the elephant ranged from 97.2° F. (36.2° C.) to 98° F. (36.7° C.). Using a clinical thermometer, we secured the rectal temperature of the male elephant and found it to be 35.9° C. On two occasions the thermometer was thrust quickly into freshly passed feces, and temperature records secured of 36.2° and 36.7° C., respectively, the large mass of feces losing heat slowly. Thus the elephant apparently has a rectal temperature slightly lower than the average commonly assumed for man.

The skin of the rhinoceros is much smoother than that of the elephant, making possible much more satisfactory measurements. This animal was studied almost exclusively on one side of the body and gave temperature measurements ranging from 24.1° to 27.9° C. In general the temperatures were somewhat warmer in the lower part of the body. An approximate average of 26.2° C. can be taken as the general skin temperature of

the rhinoceros (living in an environmental temperature of 19.5° C.), a value but slightly higher than that found with the two elephants. According to Dr. Blair the rectal temperature of the rhinoceros ranges from 99.7° F. (37.6° C.) to 100° F. (37.8° C.). Our single observation of the rectal temperature of this animal showed a value of 37.4° C.

Although considerable difficulty was experienced in securing the skin temperature of the hippopotamus, sufficient measurements were obtained to give a fairly clear picture of the probable temperature distribution. The temperatures ranged from 20.8° C. on the back to as high as 30.9° C. on the belly. An average figure for the temperature of the whole skin is probably not far from 25° C. In general the lower part of the body was found to be much warmer than the back, the temperature differences being greater with the hippopotamus than with the other three animals. This may be partly due to the fact that there was considerable vaporization of water from the skin, for the skin of the hippopotamus was much moister than that of the other two animals, although he had been out of water for several hours in an environmental temperature of approximately 19.5° C. prior to the actual temperature measurements. As a matter of fact, the temperatures of the dry and wet bulbs near the animal were 19.6° and 11.9° C., respectively. We have been unable to find any records of the rectal temperature of the hippopotamus.

To sum up, then, it can be seen that this group of animals, with a rectal temperature essentially that of man, lives in captivity in a temperature environment of about 19.5° C. with a continuous surface temperature, on the average, but 6 to 7 degrees above the environmental temperature. Man, independent of external temperature as a result of the use of clothing, has adjusted himself to a very much higher skin temperature, although this is still a greatly variable factor, averaging under clothing not far from 33° C. The direct measurement of the heat loss of these huge animals presents engineering problems rather difficult to solve. It is to be hoped that the indirect method of calorimetry (through the measurement of the oxygen consumption and the carbon-dioxide production) under these conditions of internal, environmental, and skin temperatures, may be employed to contribute further to our knowledge of the fundamental laws governing heat loss in the warm-blooded animal unprotected by a fur coating. It must be recognized, however, that with the elephant, rhinoceros, and hippopotamus, as the name of this group of animals implies, extraordinarily thick skins have been developed and thus in a way these animals carry around, instead of fur, an extra heavy plating of epidermis which, without doubt, measurably retards heat loss.

The details of this study are to be found published in the *American Journal of Physiology* for July, 1921.

[1] Benedict, Miles, and Johnson, these PROCEEDINGS, 5, 1919 (218).